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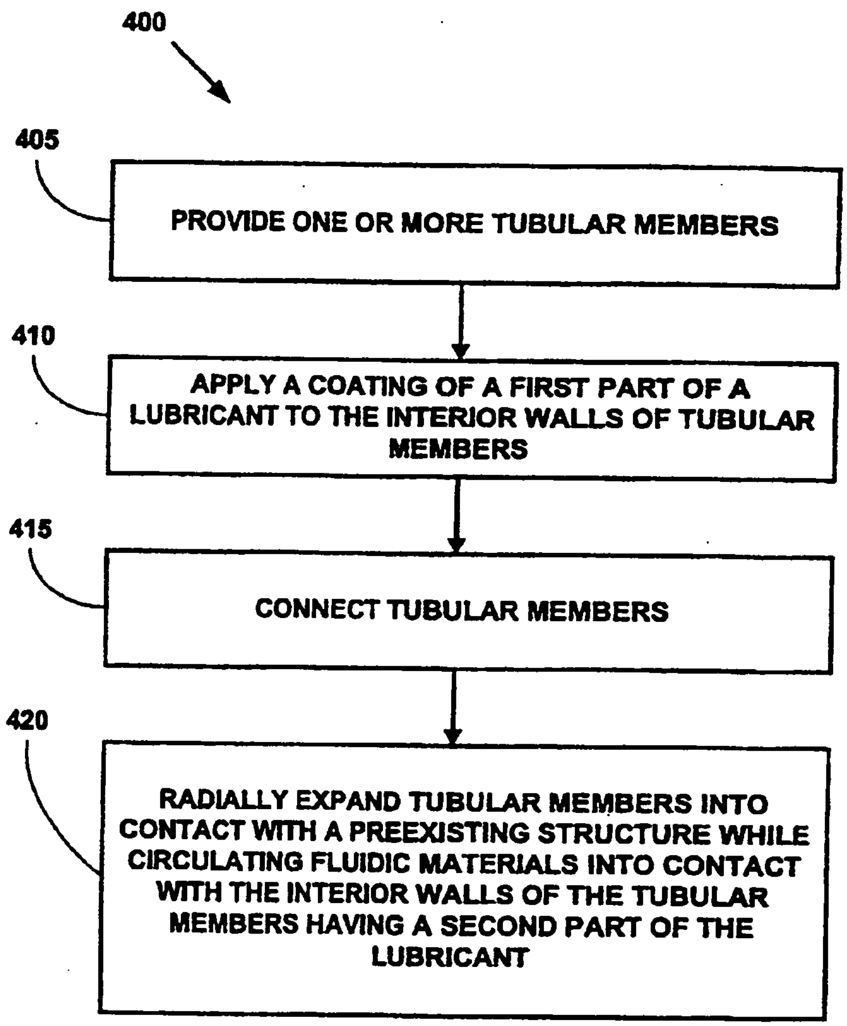

FIGURE 1

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LUBRICANT COATING FOR EXPANDABLE TUBULAR MEMBERS

Background of the Invention

This invention relates generally to tubular members, and in particular to lubricant coatings for tubular members that are formed using expandable tubing.

Conventionally, when a wellbore is created, a number of casings are installed in the borehole to prevent collapse of the borehole wall and to prevent undesired outflow of drilling fluid into the formation or inflow of fluid from the formation into the borehole. The borehole is drilled in intervals whereby a casing which is to be installed in a lower borehole interval is lowered through a previously installed casing of an upper borehole interval. As a consequence of this procedure the casing of the lower interval is of smaller diameter than the casing of the upper interval. Thus, the casings are in a nested arrangement with casing diameters decreasing in downward direction. Cement annuli are provided between the outer surfaces of the casings and the borehole wall to seal the casings from the borehole wall. As a consequence of this nested arrangement a relatively large borehole diameter is required at the upper part of the wellbore. Such a large borehole diameter involves increased costs due to heavy casing handling equipment, large drill bits and increased volumes of drilling fluid and drill cuttings. Moreover, increased drilling rig time is involved due to required cement pumping, cement hardening, required equipment changes due to large variations in hole diameters drilled in the course of the well, and the large volume of cuttings drilled and removed.

The present invention is directed to overcoming one or more of the limitations of the existing procedures for forming wellbores.

Summary of the Invention

According to a first aspect of the present invention there is provided a method of coupling an expandable tubular assembly including one or more tubular members to a preexisting structure, comprising:

coating the interior surfaces of the tubular members with a first part of a lubricant;

positioning the tubular members within a preexisting structure;

circulating a fluidic material including a second part of the lubricant into contact with the coating of the first part of the lubricant; and

radially expanding the tubular members into contact with the preexisting structure.

According to a further aspect of the present invention there is provided an apparatus, comprising:

a preexisting structure; and

one or more tubular members coupled to the preexisting structure by the process of:

coating the interior surfaces of the tubular members with a first part of a lubricant;

positioning the tubular members within a preexisting structure;

circulating a fluidic materials having a second part of the lubricant into contact with the coating of the first part of the lubricant; and

radially expanding the tubular members into contact with the preexisting structure.

Preferably, the tubular members comprise wellbore casings.

Preferably, the tubular members comprise underground pipes.

Preferably, the tubular members comprise structural supports.

Preferably, the lubricant comprises a metallic soap.

Preferably, the lubricant comprises zinc phosphate.

Preferably, the lubricant provides a coefficient of friction of between 0.02 to 0.08.

Preferably, the second part of the lubricant is selected from the group consisting of:

sodium stearates, calcium stearates, zinc stearates, zinc phosphate, manganese phosphate, polytetrafluoroethylene, molybdenum disulfide, and metallic soaps.

Preferably, the lubricant provides a sliding coefficient of friction less than 0.20.

Preferably, the second part of the lubricant is selected from the group consisting of:

polyacrylamide polymers, AMPS-acrylamide copolymers, modified cellulose derivatives, hydroxyethylcellulose, carboxymethyl hydroxyethyl cellulose, polyvinyl alcohol polymers, polyvinyl acetate polymers, polyvinyl alcohol/vinyl acetate copolymers, polyvinyl pyrrolidone and copolymers including polyolefins, latexes, styrene butadiene latex, urethane latexes, styrene-maleic annhydride copolymers, viscosity index improvers for motor oils, polyacrylate esters, block copolymers including

styrene, block copolymers including isoprene butadiene, block copolymers including ethylene, and ethylene acrylic acid copolymers.

Preferably, the second part of the lubricant is selected from the group consisting of:

graphite, molybdenum disulfide, lead powder, antimony oxide, poly tetrafluoroethylene, and silicone polymers.

Preferably, the lubricant comprises a suspension of particles in a carrier solvent.

Preferably, the first part of the lubricant is selected from the group consisting of:

manganese phosphate, zinc phosphate, and iron phosphate.

Preferably, the first part of the lubricant comprises 1 to 90 percent solids by volume.

Preferably the first part of the lubricant comprises 5 to 70 percent solids by volume.

Preferably, the first part of the lubricant comprises 15 to 50 percent solids by volume.

Preferably, the first part of the lubricant comprises:

5 to 80 percent graphite;

5 to 80 percent molybdenum disulfide;

1 to 40 percent PTFE; and

1 to 40 percent silicone polymers.

Preferably, the lubricant comprises one or more of the following: ester; sulfurized oil; alkanolamides; amine; amine salt; olefin; polyolefins; C-8 to C-18 linear alcohol; derivative of C-8 to C-18 linear alcohol including ester; derivative of C-8 to C-18 linear alcohol including amine; derivative of C-8 to C-18 linear alcohol including carboxylate; sulfonate; polyethylene glycol; silicone; siloxane; dinonyl phenol; and ethylene oxide/propylene oxide block copoloymers.

Preferably, the tubular members comprise wellbore casings.

Preferably, the tubular members comprise underground pipes.

Preferably, the tubular members comprise structural supports.

Preferably, the lubricant comprises a metallic soap.

Preferably, the lubricant comprises zinc phosphate.

Preferably, the lubricant provides a coefficient of friction of between 0.02 to 0.08.

Preferably, the second part of the lubricant is selected from the group consisting of:

sodium stearates, calcium stearates, zinc stearates, zinc phosphate, manganese phosphate, polytetrafluoroethylene, molybdenum disulfide, and metallic soaps.

Preferably, the lubricant provides a sliding coefficient of friction less than 0.20.

Preferably, the second part of the lubricant is selected from the group consisting of:

polyacrylamide polymers, AMPS-acrylamide copolymers, modified cellulose derivatives, hydroxyethylcellulose, carboxymethyl hydroxyethyl cellulose, polyvinyl alcohol polymers, polyvinyl acetate polymers, polyvinyl alcohol/vinyl acetate copolymers, polyvinyl pyrrolidone and copolymers including polyolefins, latexes, styrene butadiene latex, urethane latexes, styrene-maleic annhydride copolymers, viscosity index improvers for motor oils, polyacrylate esters, block copolymers including styrene, block copolymers including isoprene butadiene, block copolymers including ethylene, and ethylene acrylic acid copolymers.

Preferably, the second part of the lubricant is selected from the group consisting of:

graphite, molybdenum disulfide, lead powder, antimony oxide, poly tetrafluoroethylene, and silicone polymers.

Preferably, the lubricant comprises a suspension of particles in a carrier solvent.

Preferably, the first part of the lubricant is selected from the group consisting of: manganese phosphate, zinc phosphate, and iron phosphate.

Preferably, the first part of the lubricant comprises 1 to 90 percent solids by volume.

Preferably, the first part of the lubricant comprises 5 to 70 percent solids by volume.

Preferably, the first part of the lubricant comprises 15 to 50 percent solids by volume.

Preferably, the first part of the lubricant comprises:

5 to 80 percent graphite;

5 to 80 percent molybdenum disulfide;

1 to 40 percent PTFE; and

1 to 40 percent silicone polymers.

Preferably, the lubricant comprises one or more of the following: ester; sulfurized oil; alkanolamides; amine; amine salt; olefin; polyolefins; C-8 to C-18 linear alcohol; derivative of C-8 to C-18 linear alcohol including ester; derivative of C-8 to C-18 linear alcohol including amine; derivative of C-8 to C-18 linear alcohol including carboxylate; sulfonate; polyethylene glycol; silicone; siloxane; dinonyl phenol; and ethylene oxide/propylene oxide block copolymers.

Brief Description of the Drawings

For a better understanding of the present invention, and to show more clearly how it may be carried into effect, reference will now be made, by way of example, to the accompanying drawing, in which:-

Fig. 1 is a flow chart illustrating a method for coupling a plurality of tubular members to a preexisting structure.

Detailed Description

As illustrated in Fig. 1, a method 400 for forming and/or repairing a wellbore casing, pipeline, or structural support includes the steps of: (1) providing one or more tubular members in step 405; (2) applying a coating including a first part of a lubricant to the interior walls of the tubular members in step 410; (3) coupling the first and second tubular members in step 415; and (4) radially expanding the tubular members into contact with the preexisting structure while also circulating fluidic materials into contact with the interior walls of the tubular members having a second part of the lubricant in step 420.

In step 410, a coating including a first part of a lubricant is applied to the interior walls of the tubular members. The first part of the lubricant forms a first part of a metallic soap. The first part of the lubricant coating includes zinc phosphate.

In step 420, a second part of the lubricant is circulated within a fluidic carrier into contact with the coating of the first part of the lubricant applied to the interior walls of the tubular members. The first and second parts react to form a lubricating layer between the interior walls of the tubular members, and the exterior surface of the expansion cone. In this manner, a lubricating layer is provided in exact concentration, exactly when and where it is needed. Furthermore, because the second part of the lubricant is circulated in a carrier fluid, the dynamic interface between the interior surfaces of the tubular members, 205 and 215, and the exterior surface of the expansion cone is also preferably provided with hydrodynamic lubrication. The first

and second parts of the lubricant react to form a metallic soap. The second part of the lubricant is sodium, calcium and/or zinc stearate.

In several experimental operations of the method 400, the following observations were made regarding lubricant coatings for expandable tubular members:

(1) boundary lubrication with a lubricant coating having high adhesion (high film/shear strength) to the expandable tubular is the single-most important lubricant/lubrication process in the radial expansion process;

(2) hydrodynamic lubrication plays a secondary role in the lubrication process;

(3) expandable tubular lubricant coating offers the more reliable and more effective form of boundary lubrication;

(4) a liquid lubricant viscosity and/or film strength that provides effective, consistent boundary lubrication typically limits the effectiveness of additives for the mud alone to provide the necessary lubrication while maintaining drilling fluid properties (rheology, toxicity);

(5) consistent reductions of 20 to 25 percent in propagation force during the radial expansion process (compared to uncoated expandable tubular control results) were obtained with the following dry film coatings: (1) polytetrafluoroethylene (PTFE), (2) molybdenum disulfide, and (3) metallic soap (stearates), these results are for laboratory tests on one inch dry pipe, in the absence of any drilling fluid;

(6) a 20 to 25 percent reduction in propagation force during the radial expansion process was observed;

(7) synthetic oil muds do not typically provide sufficient, reliable lubrication for uncoated pipe;

(8) the coefficient of friction for expandable tubular lubricant coatings remains essentially constant across a wide temperature range;

(9) the expected application range for expandable tubular casing expansion is between 40 °F and 400 °F (4°C and 204°C), this range is well within the essentially constant range for coefficient of friction for good coatings; and

(10) good extreme pressure boundary lubricants have a characteristic of performing better (lower coefficients of friction) as the load increases, coefficients of friction between 0.02 and 0.08 are reported for some coatings.

The optimum lubrication for in-situ expandable tubular radial expansion operations using the method 400 includes a combination of lubrication techniques and lubricants. These can be summarized as follows: (1) extreme pressure lubricants/lubrication techniques; and (2) hydrodynamic lubrication from the fluid in the pipe during expansion.

Extreme pressure lubrication is preferably provided by: (1) liquid extreme pressure lubricants added to the fluid (e.g., drilling fluid, etc) in contact with the internal

surface of the expandable tubular during the radial expansion process, and/or (2) solid lubricants added to the fluid added to, or contained within, the fluid in contact with the internal surface of the expandable tubular member during the radial expansion process, and/or (3) solid lubricants applied to the internal surface of the expandable tubular member to be radially expanded, and/or (4) combinations of (1), (2) and (3) above.

Liquid extreme pressure lubricant additives preferably work by chemically adhering to or being strongly attracted to the surface of the expandable tubular to be expanded. These types of liquid extreme pressure lubricant additives preferably form a 'film' on the surface of the expandable tubular member. The adhesive strength of this film is preferably greater than the shearing force along the internal surface of the expandable tubular member during the radial expansion process. This adhesive force is referred to as film strength. The film strength can be increased by increasing the viscosity of the fluid. Common viscosifiers, such as polymeric additives, are preferably added to the fluid in contact with the internal surface of the expandable tubular member during the radial expansion process to increase lubrication. These liquid extreme pressure lubricant additives include one or more of the following: polyacrylamide polymers, AMPS-acrylamide copolymers, modified cellulose derivatives such as, for example, hydroxyethylcellulose, carboxymethyl hydroxyethyl cellulose, polyvinyl alcohol polymers, polyvinyl acetate polymers, polyvinyl alcohol/vinyl acetate copolymers, polyvinyl pyrrolidone and copolymers including polyolefins, latexes such as, for example, styrene butadiene latex, urethane latexes, styrene-maleic annhydride copolymers, viscosity index improvers for motor oils such as polyacrylate esters, block copolymers including styrene, isoprene butadiene and ethylene, ethylene acrylic acid copolymers.

Extreme pressure lubrication is provided using solid lubricants that are applied to the internal surface of the expandable tubular member. These solid lubricants can be applied using various conventional methods of applying a film to a surface. These solid lubricants are applied in a manner that ensures that the solid lubricants remain on the surface of the expandable tubular member during installation and radial expansion of the expandable tubular member. The solid lubricants preferably include one or more of the following: graphite, molybdenum disulfide, lead powder, antimony oxide, poly tetrafluoroethylene (PTFE), or silicone polymers. Furthermore, blends of these solid lubricants are preferred.

The solid lubricants are applied directly to the expandable tubulars as coatings. The coating of the solid lubricant preferably includes a binder to help hold or fix the solid lubricant to the expandable tubular. The binders preferably include curable resins such as, for example, epoxies, acrylic, urea-formaldehyde, melamine formaldehyde, furan based resins, acetone formaldehyde, phenolic, alkyd resins, silicone modified alkyd resins, etc. The binder is preferably selected to withstand the expected temperature range, pH, salinity and fluid types during the installation and radial expansion operations. Polymeric materials are preferably used to bind the solid lubricants to the expandable tubular such as, for example, "self-adhesive" polymers such as those copolymers or terpolymers based upon vinyl acetate, vinyl chloride, maleic annhydride/maleic acid, and ethylene-acrylic acid copolymers, ethylene-methacrylic acid copolymers and ethylene-vinyl acetate copolymers. The solid lubricants are applied as suspensions of fine particles in a carrier solvent without the presence/use of a chemical binder.

The solid lubricant coating and the liquid lubricant additive (added to the fluid in contact with the internal surface of the expandable tubular member during the radial expansion process) interact during the radial expansion process to improve the overall lubrication. For phosphate solid lubricant coatings, manganese phosphate is preferred over zinc or iron phosphate because it more effectively attracts and retains liquid lubricant additives such as oils, esters, amides, etc.

Solid lubricant coatings use binders that provide low friction that is enhanced under extreme pressure conditions by the presence of the solid lubricant. Solid lubricant coatings includes one or more of the following: graphite, molybdenum disulfide, silicone polymers and polytetrafluoroethylene (PTFE). Blends of these materials are used since each material has lubrication characteristics that optimally work at different stages in the radial expansion process. A solid, dry film lubricant coating for the internal surface of the expandable tubular includes: (1) 1 to 90 percent solids by volume; (2) more preferably, 5 to 70 percent solids by volume; and (3) most preferably, 15 to 50 percent solids by volume. The solid lubricants include: (1) 5 to 80 percent graphite; (2) 5 to 80 percent molybdenum disulfide; (3) 1 to 40 percent PTFE; and (4) 1 to 40 percent silicone polymers.

The liquid lubricant additives include one or more of the following: (1) esters including: (a) organic acid esters (preferably fatty acid esters) such as, for example, trimethylol propane, isopropyl, penterithritol, n-butyl, etc.; (b) glycerol tri(acetoxy stearate) and N,N' ethylene bis 12 hydroxystearate and octyl hydroxystearate; (c)

phosphate and phosphite such as, for example, butylated triphenyl phosphate and isodiphenyl phosphate; (2) sulfurized natural and synthetic oils; (3) alkanolamides such as, for example, coco diethanolamide; (4) amines and amine salts; (5) olefins and polyolefins; (6) C-8 to C-18 linear alcohols and derivatives containing or consisting of esters, amines, carboxylates, etc.; (7) overbased sulfonates such as, for example, calcium sulfonate, sodium sulfonate, magnesium sulfonate; (8) polyethylene glycols; (9) silicones and siloxanes such as, for example, dimethylpolysiloxanes and fluorosilicone derivatives; (10) dinonyl phenols; and (11) ethylene oxide/propylene oxide block copolymers.

CLAIMS

1. A method of coupling an expandable tubular assembly including one or more tubular members to a preexisting structure, comprising:

coating the interior surfaces of the tubular members with a first part of a lubricant;

positioning the tubular members within a preexisting structure;

circulating a fluidic material including a second part of the lubricant into contact with the coating of the first part of the lubricant; and

radially expanding the tubular members into contact with the preexisting structure.

2. An apparatus, comprising:

a preexisting structure; and

one or more tubular members coupled to the preexisting structure by the process of:

coating the interior surfaces of the tubular members with a first part of a lubricant;

positioning the tubular members within a preexisting structure;

circulating a fluidic materials having a second part of the lubricant into contact with the coating of the first part of the lubricant; and

radially expanding the tubular members into contact with the preexisting structure.

3. The method of claim 1, wherein the tubular members comprise wellbore casings.

4. The method of claim 1, wherein the tubular members comprise underground pipes.

5. The method of claim 1, wherein the tubular members comprise structural supports.

6. The method of claim 1, wherein the lubricant comprises a metallic soap.

7. The method of claim 1, wherein the lubricant comprises zinc phosphate.

8. The method of claim 1, wherein the lubricant provides a coefficient of friction of between 0.02 to 0.08.

9. The method of claim 1, wherein the second part of the lubricant is selected from the group consisting of:

sodium stearates, calcium stearates, zinc stearates, zinc phosphate, manganese phosphate, polytetrafluoroethylene, molybdenum disulfide, and metallic soaps.

10. The method of claim 1, wherein the lubricant provides a sliding coefficient of friction less than 0.20.

11. The method of claim 1, wherein the second part of the lubricant is selected from the group consisting of:

polyacrylamide polymers, AMPS-acrylamide copolymers, modified cellulose derivatives, hydroxyethylcellulose, carboxymethyl hydroxyethyl cellulose, polyvinyl alcohol polymers, polyvinyl acetate polymers, polyvinyl alcohol/vinyl acetate copolymers, polyvinyl pyrrolidone and copolymers including polyolefins, latexes, styrene butadiene latex, urethane latexes, styrene-maleic annhydride copolymers, viscosity index improvers for motor oils, polyacrylate esters, block copolymers including styrene, block copolymers including isoprene butadiene, block copolymers including ethylene, and ethylene acrylic acid copolymers.

12. The method of claim 1, wherein the second part of the lubricant is selected from the group consisting of:

graphite, molybdenum disulfide, lead powder, antimony oxide, poly tetrafluoroethylene, and silicone polymers.

13. The method of claim 1, wherein the lubricant comprises a suspension of particles in a carrier solvent.

14. The method of claim 1, wherein the first part of the lubricant is selected from the group consisting of:

manganese phosphate, zinc phosphate, and iron phosphate.

15. The method of claim 1, wherein the first part of the lubricant comprises:
1 to 90 percent solids by volume.

16. The method of claim 15, wherein the first part of the lubricant comprises:
5 to 70 percent solids by volume.

17. The method of claim 16, wherein the first part of the lubricant comprises:
15 to 50 percent solids by volume.

18. The method of claim 1, wherein the first part of the lubricant comprises:
5 to 80 percent graphite;
5 to 80 percent molybdenum disulfide;
1 to 40 percent PTFE; and
1 to 40 percent silicone polymers.

19. The method of claim 1, wherein the lubricant comprises one or more of the following: ester; sulfurized oil; alkanolamides; amine; amine salt; olefin; polyolefins; C-8 to C-18 linear alcohol; derivative of C-8 to C-18 linear alcohol including ester; derivative of C-8 to C-18 linear alcohol including amine; derivative of C-8 to C-18 linear alcohol including carboxylate; sulfonate; polyethylene glycol; silicone; siloxane; dinonyl phenol; and ethylene oxide/propylene oxide block copoloymers.

20. The apparatus of claim 2, wherein the tubular members comprise wellbore casings.

21. The apparatus of claim 2, wherein the tubular members comprise underground pipes.

22. The apparatus of claim 2, wherein the tubular members comprise structural supports.

23. The apparatus of claim 2, wherein the lubricant comprises a metallic soap.

24. The apparatus of claim 2, wherein the lubricant comprises zinc phosphate.

25. The apparatus of claim 2, wherein the lubricant provides a coefficient of friction of between 0.02 to 0.08.

26. The apparatus of claim 2, wherein the second part of the lubricant is selected from the group consisting of:

sodium stearates, calcium stearates, zinc stearates, zinc phosphate, manganese phosphate, polytetrafluoroethylene, molybdenum disulfide, and metallic soaps.

27. The apparatus of claim 2, wherein the lubricant provides a sliding coefficient of friction less than 0.20.

28. The apparatus of claim 2, wherein the second part of the lubricant is selected from the group consisting of:

polyacrylamide polymers, AMPS-acrylamide copolymers, modified cellulose derivatives, hydroxyethylcellulose, carboxymethyl hydroxyethyl cellulose, polyvinyl alcohol polymers, polyvinyl acetate polymers, polyvinyl alcohol/vinyl acetate copolymers, polyvinyl pyrrolidone and copolymers including polyolefins, latexes, styrene butadiene latex, urethane latexes, styrene-maleic annhydride copolymers, viscosity index improvers for motor oils, polyacrylate esters, block copolymers including styrene, block copolymers including isoprene butadiene, block copolymers including ethylene, and ethylene acrylic acid copolymers.

29. The apparatus of claim 2, wherein the second part of lubricant is selected from the group consisting of:

graphite, molybdenum disulfide, lead powder, antimony oxide, poly tetrafluoroethylene, and silicone polymers.

30. The apparatus of claim 2, wherein the lubricant comprises a suspension of particles in a carrier solvent.

31. The apparatus of claim 2, wherein the first part of the lubricant is selected from the group consisting of:

manganese phosphate, zinc phosphate, and iron phosphate.

32. The apparatus of claim 2, wherein the first part of the lubricant comprises:
1 to 90 percent solids by volume.

33. The apparatus of claim 32, wherein the first part of the lubricant comprises:
5 to 70 percent solids by volume.

34. The apparatus of claim 33, wherein the first part of the lubricant comprises:
15 to 50 percent solids by volume.

35. The apparatus of claim 2, wherein the first part of the lubricant comprises:
5 to 80 percent graphite;
5 to 80 percent molybdenum disulfide;
1 to 40 percent PTFE; and
1 to 40 percent silicone polymers.

36. The apparatus of claim 2, wherein the lubricant comprises one or more of the following: ester; sulfurized oil; alkanolamides; amine; amine salt; olefin; polyolefins; C-8 to C-18 linear alcohol; derivative of C-8 to C-18 linear alcohol including ester; derivative of C-8 to C-18 linear alcohol including amine; derivative of C-8 to C-18 linear alcohol including carboxylate; sulfonate; polyethylene glycol; silicone; siloxane; dinonyl phenol; and ethylene oxide/propylene oxide block copolymers.

gallons/minute in order to optimally provide a fluid conduit that minimizes back pressure on the apparatus 2600 when the apparatus 2600 is positioned within the wellbore casing 100.

The third valve 2710 is preferably adapted to controllably block the seventh fluid conduit 2705. In this manner, the flow of fluidic materials through the seventh fluid conduit 2705 is controlled. The third valve 2710 may be any number of conventional commercially available flow control valves. The third valve 2710 is a EZ Drill one-way check valve available from Halliburton(RTM) Energy Services in order to optimally provide one-way flow through the packer 2700 while providing a pressure seal during the radial expansion process.

As illustrated in FIG. 26a, During placement of the repair apparatus 2600 within the wellbore casing 100, the apparatus 2600 is supported by the support member 2605. During placement of the apparatus 2600 within the wellbore casing 100, fluidic materials within the wellbore casing 100 are conveyed to a location above the apparatus 2600 using the fluid conduits 2705, 2670, 2660, 2640, 2630, and 2620. In this manner, surge pressures during placement of the apparatus 2600 within the wellbore casing 100 are minimized.

Prior to placement of the apparatus 2600 in the wellbore casing 100, the outer surfaces of the apparatus 2600 are coated with a lubricating fluid to facilitate their placement the wellbore and reduce surge pressures. The lubricating fluid comprises BARO-LUB GOLD-SEAL(RTM) brand drilling mud lubricant, available from Baroid(RTM) Drilling Fluids, Inc. In this manner, the insertion of the apparatus 2600 into the wellbore casing 100 is optimized.

After placement of the apparatus 2600 within the wellbore casing 100, in step 210, the logging tool 2610 is used in a conventional manner to locate the openings 115 in the wellbore casing 100.

Once the openings 115 have been located by the logging tool 2610, in step 215, the apparatus 2600 is further positioned within the wellbore casing 100 with the sealing member 2695 placed in opposition to the openings 115.

As illustrated in FIGS. 26b and 26c, After the apparatus 2600 has been positioned with the sealing member 2695 in opposition to the openings 115, in step 220, the tubular member 2685 is radially expanded into contact with the wellbore casing 100. The tubular member 2685 is radially expanded by displacing the expansion cone 2690 in the axial direction. The expansion cone 2690 is displaced in the axial direction by pressurizing the interior chamber 2715. The interior chamber 2715 is pressurized by pumping fluidic materials into the interior chamber 2715 using the pump 2625.

The pump 2625 pumps fluidic materials from the region above and proximate to the apparatus 2600 into the interior chamber 2715 using the fluid conduits 2620, 2640, 2660, and 2670. In this manner, the interior chamber 2715 is pressurized and the expansion cone 2690 is displaced in the axial direction. In this manner, the tubular member 2685 is radially expanded into contact with the wellbore casing 100. The interior chamber 2715 is pressurized to operating pressures ranging from about 0 to 12,000 psi using flow rates ranging from about 0 to 500 gallons/minute. Fluidic materials within the interior chamber 2720 displaced by the axial movement of the expansion cone 2690 are conveyed to a location above the apparatus 2600 by the fluid conduit 2650. During the pumping of fluidic materials into the interior chamber 2715 by the pump 2625, the tubular member 2685 is maintained in a substantially stationary position.

As illustrated in FIG. 26d, after the completion of the radial expansion of the tubular member 2685, the locking member 2680 and packer 2700 are decoupled from the tubular member 2685, and the apparatus 2600 is removed from the wellbore casing 100. During the removal of the apparatus 2600 from the wellbore casing 100, fluidic materials above the apparatus 2600 are conveyed to a location below the apparatus 2600 using the fluid conduits 2620, 2630, 2640, 2660, and 2670. In this manner, the removal of the apparatus 2600 from the wellbore casing is facilitated.

As illustrated in FIG. 26e, The openings 115 in the wellbore casing 100 are sealed off by the radially expanded tubular member 2685 and the sealing member

2695. In this manner, the repair apparatus 2600 provides a compact and efficient device for repairing wellbore casings. More generally, the repair apparatus 2600 is used to repair and form wellbore casings, pipelines, and structural supports.

Although illustrative embodiments of the invention have been shown and described, a wide range of modification, changes and substitution is contemplated in the foregoing disclosure. In some instances, some features of the present invention may be employed without a corresponding use of the other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention.

TABLE FOR CONVERSION TO METRIC UNITS

0 to 12,000 psi (0 to 827.3708736 bar)

0.0625 inches (0.15875 centimetre)

0.125 inches (0.3175 centimetre)

0 to 500 gallons/minute (0 to 1,892.7059 litres/minute)

2×10^{-4} in^2 to 5×10^{-2} in^2 (5.18×10^{-4} cm^2 to 12.70×10^{-2} cm^2)

CLAIMS

1. An apparatus for repairing a tubular member, comprising:

a support member;

an expandable tubular member removably coupled to the support member;

an expansion cone movably coupled to the support member; and

a pump coupled to the support member adapted to pressurize a portion of the interior of the expandable tubular member;

wherein the expandable tubular member includes:

a first end having a first outer diameter;

an intermediate portion coupled to the first end having an intermediate outer diameter; and

a second end having a second outer diameter, and coupled to the intermediate portion;

wherein the first and second outer diameters are greater than the intermediate outer diameter.

2. The apparatus of claim 1, wherein the expandable tubular member includes: a coating of a lubricant.

3. The apparatus of claim 1, wherein the expandable tubular member includes: a coating of a first component of a lubricant.

4. The apparatus of claim 1, wherein the expandable tubular member includes: a sealing member coupled to the outer surface of the expandable tubular member.

5. The apparatus of claim 1, wherein the first end, second end, and intermediate portion of the expandable tubular member have wall thicknesses t_1, t_2, and t_{INT} and inside diameters D_1, D_2 and D_{INT}; and the relationship between the wall thicknesses t_1, t_2, and t_{INT} , the inside diameters D_1, D_2 and D_{INT}, the inside diameter D_{TUBE} of the

tubular member that the expandable tubular member will be inserted into, and the outside diameter D_{cone} of the expansion cone is given by the following expression:

$$D_{TUBE} - 2 * t_1 \geq D_1 \geq \frac{1}{t_1}\left[(t_1 - t_{INT}) * D_{CONE} + t_{INT} * D_{INT}\right]$$

where $t_1 = t_2$; and

$D_1 = D_2$.

6. The apparatus of claim 1, wherein the expandable tubular member includes:
a sealing member coupled to the outside surface of the intermediate portion.

7. The apparatus of claim 1, wherein the expandable tubular member includes:
a first transition portion coupled to the first end and the intermediate portion inclined at a first angle; and
a second transition portion coupled to the second end and the intermediate portion inclined at a second angle;
wherein the first and second angles range from 5 to 45 degrees.

8. The apparatus of claim 1, wherein the expansion cone includes:
an expansion cone surface having an angle of attack ranging from 10 to 40 degrees.

9. The apparatus of claim 1, wherein the expansion cone includes:
a first expansion cone surface having a first angle of attack; and
a second expansion cone surface having a second angle of attack;
wherein the first angle of attack is greater than the second angle of attack.

10. The apparatus of claim 1, wherein the expansion cone includes:
an expansion cone surface having a substantially parabolic profile.

11. The apparatus of claim 1, wherein the expansion cone includes:

an inclined surface including one or more lubricating grooves.

12. The apparatus of claim 11, wherein the expansion cone includes:

one or more internal lubricating passages coupled to each of the lubricating grooves.

13. An apparatus for repairing a tubular member, comprising:

a support member;

an expandable tubular member removably coupled to the support member;

an expansion cone movably coupled to the support member; and

a pump coupled to the support member adapted to pressurize a portion of the interior of the expandable tubular member;

wherein the expansion cone includes an inclined surface including one or more lubricating grooves.

14. An apparatus for repairing a tubular member, comprising:

a support member;

an expandable tubular member removably coupled to the support member;

an expansion cone movably coupled to the support member; and

a pump coupled to the support member adapted to pressurize a portion of the interior of the expandable tubular member;

wherein the expansion cone includes an inclined surface including one or more lubricating grooves; and

wherein the expansion cone includes one or more internal lubricating passages coupled to each of the lubricating grooves.

15. An apparatus for repairing a tubular member, comprising:

a support member;

an expandable tubular member removably coupled to the support member;

a tubular expansion cone movably coupled to the support member; and

a pump coupled to the support member adapted to pressurize a portion of the interior of the expandable tubular member.

16. The apparatus of claim 15, wherein the expandable tubular member includes:

a coating of a lubricant.

17. The apparatus of claim 15, wherein the expandable tubular member includes:

a coating of a first component of a lubricant.

18. The apparatus of claim 15, wherein the expandable tubular member includes:

a sealing member coupled to the outer surface of the expandable tubular member.

19. The apparatus of claim 15, wherein the expandable tubular member includes:

a first end having a first outer diameter;

an intermediate portion coupled to the first end having an intermediate outer diameter; and

a second end having a second outer diameter, and coupled to the intermediate portion;

wherein the first and second outer diameters are greater than the intermediate outer diameter.

20. The apparatus of claim 19, wherein the first end, second end, and intermediate portion of the expandable tubular member have wall thicknesses t_1, t_2, and t_{INT} and inside diameters D_1, D_2 and D_{INT}; and wherein the relationship between the wall thicknesses t_1, t_2, and t_{INT}, the inside diameters D_1, D_2 and D_{INT}, the inside diameter D_{TUBE} of the tubular member that the expandable tubular member will be

inserted into, and the outside diameter D_{cone} of the expansion cone is given by the following expression:

$$D_{TUBE} - 2 * t_1 \geq D_1 \geq \frac{1}{t_1}\left[(t_1 - t_{INT}) * D_{CONE} + t_{INT} * D_{INT}\right]$$

where $t_1 = t_2$; and

$D_1 = D_2$.

21. The apparatus of claim 19, wherein the expandable tubular member includes: a sealing member coupled to the outside surface of the intermediate portion.

22. The apparatus of claim 19, wherein the expandable tubular member includes:

a first transition portion coupled to the first end and the intermediate portion inclined at a first angle; and

a second transition portion coupled to the second end and the intermediate portion inclined at a second angle;

wherein the first and second angles range from 5 to 45 degrees.

23. The apparatus of claim 15, wherein the tubular expansion cone includes: an expansion cone surface having an angle of attack ranging from 10 to 40 degrees.

24. The apparatus of claim 15, wherein the tubular expansion cone includes:

a first expansion cone surface having a first angle of attack; and

a second expansion cone surface having a second angle of attack;

wherein the first angle of attack is greater than the second angle of attack.

25. The apparatus of claim 15, wherein the tubular expansion cone includes: an expansion cone surface having a substantially parabolic profile.

26. The apparatus of claim 15, wherein the tubular expansion cone includes:

an inclined surface including one or more lubricating grooves.

27. The apparatus of claim 26, wherein the tubular expansion cone includes:
one or more internal lubricating passages coupled to each of the lubricating grooves.

28. The apparatus of claim 13, wherein the expandable tubular member includes:
a sealing member coupled to the outer surface of the expandable tubular member.

29. The apparatus of claim 13, wherein the expandable tubular member includes:
a first end having a first outer diameter;
an intermediate portion coupled to the first end having an intermediate outer diameter; and
a second end having a second outer diameter, and coupled to the intermediate portion;
wherein the first and second outer diameters are greater than the intermediate outer diameter.

30. The apparatus of claim 13, wherein the expandable tubular member includes:
a first transition portion coupled to a first end and an intermediate portion inclined at a first angle; and
a second transition portion coupled to a second end and the intermediate portion inclined at a second angle;
wherein the first and second angles range from 5 to 45 degrees.

31. The apparatus of claim 13, wherein the expansion cone includes:
an expansion cone surface having an angle of attack ranging from 10 to 40 degrees.

32. The apparatus of claim 13, wherein the expansion cone includes:

a first expansion cone surface having a first angle of attack; and

a second expansion cone surface having a second angle of attack;

wherein the first angle of attack is greater than the second angle of attack.

33. The apparatus of claim 13, wherein the expansion cone includes:

an expansion cone surface having a substantially parabolic profile.

34. The apparatus of claim 14, wherein the expandable tubular member includes:

a sealing member coupled to the outer surface of the expandable tubular member.

35. The apparatus of claim 14, wherein the expandable tubular member includes:

a first end having a first outer diameter;

an intermediate portion coupled to the first end having an intermediate outer diameter; and

a second end having a second outer diameter, and coupled to the intermediate portion;

wherein the first and second outer diameters are greater than the intermediate outer diameter.

36. The apparatus of claim 14, wherein the expandable tubular member includes:

a first transition portion coupled to a first end and an intermediate portion inclined at a first angle; and

a second transition portion coupled to a second end and the intermediate portion inclined at a second angle;

wherein the first and second angles range from 5 to 45 degrees.

37. The apparatus of claim 14, wherein the expansion cone includes:

an expansion cone surface having an angle of attack ranging from 10 to 40 degrees.

38. The apparatus of claim 14, wherein the expansion cone includes:
a first expansion cone surface having a first angle of attack; and
a second expansion cone surface having a second angle of attack;
wherein the first angle of attack is greater than the second angle of attack.

39. The apparatus of claim 14, wherein the expansion cone includes:
an expansion cone surface having a substantially parabolic profile.